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ABSTRACT

The purpose of this study was to examine in detail the experiences of non-major undergraduate students progressing through an introductory physics course taught in a four-year research university, to discover why the students have these experiences, and to uncover the consequences of those experiences. A theory was developed for relating experiences of non-majors to other science-shy students attempting to learn science. A qualitative study of 26 students, one professor, one teaching assistant who taught the lab sessions, and one lab supervisor in a summer session of an introductory physics course taught at a state research university was conducted. The study describes reactions of introductory college science instructors to the experiences of the students, and provides implications for introductory college science teaching. Analysis of results finds that activities engaged in by students did not contribute to most students' understandings of the content but rather to simply getting through the course. Suggestions are made for improving physics instruction in a traditional classroom. (LZ)

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BEATING THE SYSTEM: CONFRONTING STUDENT BEHAVIORS THAT INHIBIT CONCEPTUAL UNDERSTANDING OF INTRODUCTORY COLLEGE PHYSICS

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BEATING THE SYSTEM: CONFRONTING STUDENT BEHAVIORS THAT INHIBIT CONCEPTUAL UNDERSTANDING OF INTRODUCTORY COLLEGE PHYSICS

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Background of the Study

Regardless of their majors, most college students are required to enroll in and pass a physical science course. Many of these students choose to enroll in an introductory physics course. Perhaps these students come prepared for what they will encounter in lectures and lab sessions, but some may share anxiety related to the math and science knowledge required by the course. Because of the wide range of majors enrolled in the introductory physics course, teaching these students may present a variety of problems not encountered in teaching a course intended solely for physics majors. The Society for College Science Teachers (1993) has identified two major goals for introductory college science courses to incorporate: (1) to contribute to the scientific literacy and critical thinking skills of all college students, and (2) to serve as a conceptual base for subsequent courses taken. Since our technological world requires all people to become scientifically literate (Rutherford & Ahlgren, 1989), an introductory physics course could be an invitation to take other science courses (Tobias, 1985) or be a barrier rather than a bridge to further learning in the subject (Lipson & Tobias, 1991).

To address these problems, Tobias (1992) recommends that undergraduate science teaching be revitalized in order to provide conceptual understanding of science content and processes, and improve public interest in science. One suggestion is to include an integration of two disciplines of science, such as chemistry and physics, to make more meaning of each subject. Another suggestion is to cover fewer topics in greater depth to allow more time for students to grapple with meanings, as well as a modification of the lecture format to one that is more interactive. Instructors should focus on qualitative as well as quantitative knowledge for their students. Students should be encouraged to overtly engage in constructing knowledge from concrete experiences and discussions. In addition, Tobias (1991) suggests developing a classroom environment filled with a community of learners in which students feel comfortable working together and making meaning of what they are learning. Because many undergraduate students may not have had experiences to prepare them for what they may find in college science courses, and begin with trepidation because of prior experiences in science, or see it as something too difficult (Tobias, 1985) or alien to their experiences (Belenky et al, 1986) science instruction should build on what they do know. Alternative conceptions should be uncovered and addressed because students can sometimes calculate answers to textbook problems very well, and still hold unconventional ideas about physics (Tobias, 1992).

Purpose

The purpose of this study was to examine in detail the experiences of non-major undergraduate students progressing through an introductory physics course taught in a four year research university, to discover why the students have these experiences, and to uncover the consequences of those experiences. Through this study it was possible to develop a grounded theory (Bogdan & Biklen, 1992) for relating experiences of non-majors to other science-shy students attempting to learn science. The study describes reactions of introductory college science instructors to the experiences of the students, and provides implications for introductory college science teaching.

Research Methodology, Design and Procedures

The methods used in this study were qualitative in the Chicago School Tradition (Bogdan & Biklen, 1992). Chicago school methodology uses the study of a single case, person, or group, from which to draw firsthand evidence of experiences. The attempt is to see how all participants in the group experience the interactions and the setting. The goal is to describe the situation from multiple viewpoints. The design included study of 26 students, one professor, one teaching assistant who taught the lab sessions, and one lab supervisor, in a summer session of an introductory physics course taught at a state research university. The introductory physics course that was selected met several criteria. First, the course was an introductory level class designed for non-majors, and secondly the course incorporated lab as well as lecture sessions. It was also fortunate that the professor had 31 years of experience teaching this course.

The design included four stages, the first being contacting by phone and meeting with the professor to discuss the logistics of observation in the physics course. The second included hour-long interviews of the course professor, lab supervisor, lab session teaching assistant, and (in terms of grades earned) a student doing well and a student doing poorly in the course. This selection of various participants provided contextual background from different viewpoints. The interviews consisted of open-ended questions which encouraged those interviewed to talk about the course as they saw it. Descriptive field notes were taken during the interviews as they were being audiotaped. The third stage consisted of sixteen hours of participant observation of the lecture and lab sessions during which detailed field notes were taken. The major focus was on the five persons interviewed, but all relevant observations were examined and included in the study. Photographs of the classroom, bulletin boards and lab, rooms were taken to provide context of the course. Field documents such as copies of tests, student notes, and the course syllabus, were collected for analysis. A course evaluation was given to all class members to embrace the thoughts and experiences of those not interviewed, and to help understand the class as a whole.The fourth stage consisted of sharing the results with other introductory college science instructors to gain insight into their reactions. Three instructors were selected. One was a secondary science methods professor, the second was an astronomy professor who also taught introductory courses to preservice teachers, and the third was a Ph.D. physicist currently teaching high school physics and chemistry, but who has previously taught introductory college physics. Field notes were taken and reactions were recorded in the form of hour-long audiotaped discussions.

The Structure of the System

The professor wanted students to learn and develop an appreciation for physics. He differentiated the courses he teaches to majors from those he teaches to non-majors, stating that, "they (the students) have to be here. They never dreamed they'd have to take a physics course." He realized that his non-major students sometimes come to his course with "math anxiety" and "preconceived notions that physics will be difficult," so he told them to "relax" and work on problems in "small doses", and to begin by working problems they recognized. The introductory physics courses he usually teaches have 100-150 students which is much larger than this summer session which began with fifty students. He also noted that courses for majors were much smaller, often having only ten students enrolled at a time. He needed an efficient way to help a large number of students meet his goals of learning and appreciating physics. With 150 students in a class, assigning just ten homework problems would produce 1500 problems to grade, and it takes "lots of time to read them with a quality eye." This course was divided into five hours of lecture and six hours of lab per week. The lecture sessions were taught in an auditorium with theater seating, using lecture, demonstration, and modeling problems on overhead projectors as the dominate mode of instruction. The lab sessions were taught in a classroom with equipment previously set up for students to follow directions in "cookbook" fashion to complete their assignments. Labs often had little or no connection to what was being studied in lecture sessions. During one lab session the teaching assistant stated, "Pay attention because today's lab will not ever be covered in lecture." She said that she thinks students have trouble understanding the labs because they never correlate with lectures which are "needed to provide background."

During the summer session there was a total of 88 in-class hours with approximately 600 pages of text and lab manual readings to be done. For each week two lab write-ups were due as well as two homework sets of up to fourteen problems. In addition, there were three one-hour exams, one every two weeks, and one two-hour comprehensive final. The professor believed if these requirements were satisfactorily accomplished, the student would have learned the physics necessary to pass the course, and gained an appreciation for the subject.

The students began the course sharing the goals of the professor, and hoped to learn and enjoy physics. However, upon meeting the structure of the course, students found the requirements and pacing not conducive to their learning. They were also inhibited from asking questions. The professor said he didn't like to "stand up and lecture," but that he "wanted to involve the class." However, his answers to their questions lead students to believe that questions intruded on his time to impart knowledge. While neither asked questions of the students, both the professor and teaching assistant occasionally paused during their monologues to see if there were any questions. Generally there were none. One student said he "didn't know enough to ask a question" stating "it would be embarassing because people would know how lost I am." In a few instances a student would venture a question and be reminded by the professor or teaching assistant that this had already been studied and it really should be known. At one point during a lecture a male student asked a question concerning what was being covered. The professor answered the question, but then said, "It's the same triangle pattern we've been studying. You should recognize the triangle pattern by now." Students

tended to ask questions on a private rather than public basis. They tried to write everything down the professor said and wrote on the overhead during the lectures and then tried to learn it later. Some students even used the exact color pens in their notes as the professor used when writing on the overhead.

Students were graded on a curve, with a few As available in class, to be balanced by an equal number of Fs. This created intense competition, and turned student attention from cooperative work to engaging in activities they developed to help them get the top grades. Homework turned in was held to an exacting standard and had to be written correctly. If there was a unit or a word missing, points were deducted. Labs were also held to an explicit standard, and only a certain number of students could get As.

Exams also proved to be a problem. On Exam 2 only two people received As, with eight people earning Fs in this class of only 26 students. About one-third of the class failed the test, yet the professor was pleased that 13 of the students received a C or better, actually meaning that only half of the students in the class received average or above grades. The professor allowed students who received below a C to try the exam again orally to gain more points, but they were not allowed to attain a grade higher than a middle C, because it wasn't fair to the people who "got it right the first time"--those who had already earned a C or above. Exams were also graded down if students misspelled words or used punctuation incorrectly. Two females reported "crying all night" after they received back their exams.

Students focused on getting answers absolutely correct, didn't ask questions during class or lab, and felt "stressed" in the course. One female stated,"I just don't like the pressure of figuring things and having to have everything be so correct!" As one male student said, "You would think since I study eight hours a day I would at least be able to pass the test." This student, who received an F on the first exam, hired a tutor and raised his grade to a D on the second exam. The student said he was not "hating it" as much as before, but since he was an architecture major he imagined that his physics professor was "lousy" at drawing, which seemed to make it okay that he was "lousy" at physics.

Analytic Framework

Students taking undergraduate physics courses for non-majors are usually young people undergoing transitions from high school to college life. Science and engineering instructors need to take this opportunity to "sell" science to their students through making science interesting, appealing and painless, which can be done without compromising quality of instruction (Reinarz, 1991). There is considerable evidence that this is not how introductory physics is usually taught, that the traditional introductory curriculum is not well matched to many students, and efforts to correct this mismatch would help students overcome difficulties encountered (Dickie & Farrell, 1991). They define "mismatch" as curriculum which does not effectively teach introductory science to students coming in from high school to college. This curriculum does not seek to know conceptions students bring with them about science and about learning. College teachers may not realize the norm of high school studies, and high school teachers may not realize college traditions which their students must embrace if they are to be successful. Dickie and Farrell recommend teachers being aware of the factors that influence choices transitional students make in moving from high school to college. This mismatch could be extended

to include other science shy students, such as elementary teachers seeking to increase their backgrounds in science.

To address the problems discussed above, Tobias (1990) conducted several studies in which college professors and graduate students from different non-science disciplines posed as introductory science students progressing through the courses as the regular students would, but for limited time periods. She used experienced students because they would be better at reflecting on their experiences, extending the information given in class, and interpreting from multiple perspectives such as instructor and student, and would be able to gather data from a variety of sources. Shea and Taylor (1990), building on Tobias' work had four professors from different disciplines take an entire semester of physics participating in all aspects of the course. Both groups of researchers had the professors act as participant observors keeping journals of their experiences as physics students. This enabled the researchers to get picture of how a student, albeit an experienced one, would perceive learning physics. The current study used a similar methodological design involving observation, interviewing, surveying, documents from students and instructors, and photographs in order to develop descriptive data on how young, transitional students (Reinarz, 1991) experienced physics, and the consequences of their experiences.

The Analysis

Differing Goals For Learning

The professor of this introductory physics course structured it to fit the goals for his students to learn and enjoy physics. The structure of the course is efficient at what he believed allowed many students to meet those goals. He was very enthusiastic about his subject, and tried to plan interesting demonstrations from which they could learn. He obviously wished to help his students develop an appreciation for physics, and was generally required to teach a large number of students. His means and processes for his students to meet the goals consisted of assigning (1) five hours of weekly lectures, (2)six hours of weekly laboratory sessions, (3) 600 pages of text and lab manual readings, (4) two weekly sets of homework problems, (5) two weekly sets of laboratory write-ups, (6) three one-hour examinations, and (7) one two-hour comprehensive final. A related process is to reward students getting the right answers with high marks through the evaluation of the homework, laboratory write-ups, and examinations. Problems were demonstrated on two overheads, and he was careful to make sure that he always put up the problems correctly so students "wouldn't learn them wrong." As with other reports of physics instruction (Tobin, Tippins & Gallard, 1994), this professor believed if students did well in the assigned work they were meeting the goals of learning and appreciating physics. He reported enjoying lectures, talking with students "one-on-one", and "pulling off demonstrations that work."

Students discussed their frustrations in trying to learn. Students spoke about "the symbolism and terminology" being "so weird." They talked about wanting to know the "basic concepts of everything," wanting a "good grasp of things, not everything in formulas," and "We want a big picture, but only get a small grasp of things" and "They get uptight if we don't know what they're talking about." Some students began with positive attitudes, but ended thinking "physics is too hard." As one student said," I started with a good attitude, but it went down. I don't want to take this again. I would be happy

with just a C." Students were very interested in making it through introductory physics, and three were enrolled in this course for the second time. They did not intend to take this course again and were trying to find a way to pass. They hoped it would be a pleasant experience, and were delighted when one day in lab they were allowed to explore freely with liquid nitrogen. One student exclaimed,"Write down this day! Fun was had in physics lab!" Due to pacing and time constraints, however, under this system students found it difficult to focus on enjoying or understanding the material. The teaching assistant also agreed that "too much material is covered too fast. Some students don't even know the difference between velocity and accelaration--what can they be learning?" Students knew that if they didn't pass the course they would either have to take it again, or change their majors. During lab sessions students would discuss how if they didn't get answers correct it would affect their futures. One student said, "If you don't measure that correctly you won't get into medical school." They felt compelled to invent efficient ways to maximize scores and complete assignments. The system must be beat, requiring getting the right answer and passing physics to be the goal held by the student, making it necessary for the student to design a new plan for getting through the course. Students developed new ways for getting the right answers which enabled them to give the appearance of learning and enjoying physics to their professor, and to pass physics with an acceptable grade without much understanding of the concepts. (See Table One.)

Table One. Differing Views of the Course

	Professor	Student
GOAL	Students will learn and enjoy physics	1. Learn and enjoy physics (early in the course) 2. Pass the course with an acceptable grade (later in course)
METHOD	1. Set up course structure to enable student success	1. Complete required work
	2. Student will show proof of learning and enjoyment by getting the right answers	2. Get the right answers some way

New Means for Getting the Right Answers

Students developed several strategies which allowed them to complete the work at the pace required by the system. These strategies did not reinforce student learning of physics, but served to help the students structure their own system for passing the course. The strategies all shared the goals of turning in the right answers and thus passing the course.

Hide and Seek

Figuratively speaking, students have adapted a form of the well-known child's game to protect their place in the class. All students, but particularly those doing well, hid their grades, solutions, and strategies from other students. This was shown in the voluntary seating arrangement which evolved in the class. With the exception of three females who always sat together and also formed a laboratory group, no two students sat next to one another. Rather than sitting next to someone with whom to share ideas and understandings, there was always an empty seat left between them. During the laboratory sessions students did sit near one another and worked together, but completed their laboratory write-ups alone. When homework and exams were returned they quickly looked at the paper and placed it face down on their table or tucked it away in their books. Following Exam 2, the professor passed back the exams curled up so students could not see their grades until they looked. Neither student nor professor spoke, but the students quickly looked at their grades and curled up their papers again, walked briskly to their seats and hid their papers in their books. One female excitedly whispered the news that she had received an A to her friend (who received a C+), and asked her not to tell anyone. Since the professor graded on a curve, students were competing for the few top grades, and did not wish to be the ones earning the required balance of low grades. Hiding from other students allowed students who had the right answers and the highest grades to keep those answers and grades to themselves, and allowed those not doing as well some anonymity.

On the seeking side, students believed if they were known as serious-minded about physics by the professor and teaching assistant, that when grades were given more lenience would be shown to them. The professor and teaching assistant reported enjoying talking to students on an individual basis, and students capitalized on this. Students attempted to talk with the professor and teaching assistant during office hours, after class, and be known by them as persons who were apparently interested in doing well in the course. It gave them the appearance of learning and enjoying physics. One woman spoke to the professor before class to relate the information they were learning about work in physics to what she was learning in exercise physiology. She told him, "I talked to my friends in my other class and they think work can be done during exercise even if you don't move anything across the room." In doing this, she was telling the professor that she is serious about physics--she talks about it with other people outside of class and understands the concept of work as he explains it. Students also tried to maintain a high profile with the teaching assistant by coming early to the lab sessions, by joking with her and by telling and receiving personal stories. One student always asked about her weekend, and talk ensued about what others in the class did on their weekends. They "talked physics" and tried to show their interest in what they were studying to the teaching assistant. However, during lectures or lab sessions most students were extremely quiet, carefully listening, frantically taking notes, and neither asking nor answering questions. When they did ask questions they often didn't understand the answers given. One student asked his lab partner for the correct procedure since he had just asked the teaching assistant how to conduct it. He replied,"Just because I asked doesn't mean I understand anything."

Students also sought out other students who had high grades in an attempt to get the "right" answers for themselves. They would go to students whom they believed were "naturals" and attempted to uncover strategies they could use, or to simply copy papers in order to increase their grades. This strategy did not always work, because those with high grades were attempting to hide this from other students. However, one A student did admit to "feeling sorry" for a student who had failed the test, and correctly solved the make-up test for him.

Creative Waiting

Creative waiting refers to the realization that one could get the right answer, gain more points, and thereby get a higher grade by waiting to turn in homework solutions a day late. Homework problems were set to be due on a particular date. For each day the homework problems were late the student's grade was dropped ten percent. Students realized that because the problems were difficult they usually could not get full credit by completing them on time and turning them in because they would lose too many points. Their own solutions were invariably not as "correct" as was desired by the professor and teaching assistant. If they waited until the second day when the answers were posted in the student lounge they could copy those worked out answers and turn them in all correct, and even with the ten percent grade reduction, end up getting more points than they could if they turned in their incorrectly solved problems on time. One male complained that on one homework paper he lost three points because he left off the word 'net' and only wrote 'weight'. He subsequently waited for posted answers to gain more points.

Creative waiting allowed students to spend much less time on solving homework problems, and also allowed them to turn in more perfectly solved work enabling them to improve their grades. This method eventually caught up with students when exam time came because invariably through the lack of practice on the homework problems, the students would do poorly on the exams. One female said that students doing well did not resort to copying solutions and thought of it as unfair, but that she understood why some would do it. Creative waiting was considered cheating, and students who used it were given the name "lizards" by other students.

Shimmying

Shimmying is a word coined by the students. It occurred during lab sessions and stood for falsely constructing results through contriving and manipulating data obtained in experiments, always with the goal of fitting the results to the preconceived "right answer." This allowed students to receive more points and higher grades on lab reports. Shimmying was not thought of as cheating by students because the final answer was known in advance, and students were only making their data fit what they knew it should be. One student referred to labs as "fake experiments with no relation to anything we use in life. Why not make what we get fit what we need?" The students who were most adept at shimmying were those who were doing the best in class, and they were also the ones who felt the least anxiety with using it as a method to raise their grades. Shimmying didn't hold the same hazards exam-wise as creative waiting because lab reports and results were not tested. Students always tried to get the right answer prior to shimmying. Shimmying was especially evident the day the teaching assistant reminded everyone that they were, as a whole, doing too well on the labs, and there "needed to be some students doing poorly," so she was going to have to "grade harder on what they turned in." During

the projectile lab that day, one group tried several times to get the projectile pattern required by conducting their experiment as instructed in their manual. When they could not obtain the desired pattern they waited for the teaching assistant to be busy with another group, and physically tapped their metal ball on their paper in the correct pattern.

Students tended to follow the students who were shimmying because they saw them as "naturals" or "left-brained"--those who could "just see what they're supposed to know." In one lab group a female A student, self-proclaimed as the "queen of shimmying," manipulated her data to obtain a larger answer so as to have a lower margin of error. Her lab group had some problems with this, noting that you simply can't change the time, "the time it took is the time it took." She said she was doing it and that it wasn't really cheating because she knew that was how it was supposed to come out and that they could do whatever they wanted. The other students in her group, one young male and one young female, both of whom had received Ds on Exam 2, felt distressed at changing the data, and they took an additional measurement of the experiment to see if it would come out the way the A student said it should. They did not obtain the desired result, and decided to accept what the A student had contrived, because she was "smart" and knew what the answer "should be". Meanwhile the A student had gone on with the experiments, and the other students were forced to try to catch up.

A female student once said,"Our angle of deviation is just too big. We may have to resort to raising our hands." Her partner replied,"No, if we change the angle we will get zero." They wrote down a different angle than what they measured in order to get the "right answer." In another instance the students chose not to write their answer in scientific notation because then "it wouldn't look so bad" and they wouldn't have to go back and manipulate the formula to fit the right answer.

Reactions From Introductory Science Instructors

The results of this study were shared with two introductory college science professors teaching at a four year research university. One professor taught introductory astronomy to non-majors and preservice teachers, and the other taught secondary school science methods courses. Both professors were interviewed prior to reading the study to gain insight into their views of teaching. After time to read the results, they were interviewed again to get their reactions. In all cases the audiotaped interviews lasted about an hour. In addition, this study was shared with a Ph.D. physicist currently teaching high school physics and chemistry. His interview was audiotaped as well.

Both the science educator and astronomy professor agreed that what was found was really not surprising in light of the structure of the course. The astronomer said, "It confirms my horrible suspicions about how students learn. I get the impression that these behaviors are not unusual." The science educator called it a "classical example of an introductory physics course." They both agreed that when a course proceeds wherein there is pressure to cover "so-called interesting stuff" and not leave out "so-called important stuff" that there is not enough time for the students to learn everything the professor wants them to learn. The professor is "unintentionally trying to get the students to learn in one semester what it has taken him a lifetime." The physics instructor was not surprised by the class either, stating that "physics is always taught this way", but that he "always did my own work. I had no problems with tests."

The astronomer believed that such student behavior would be typical in this type of course where the pressures on the students to obtain the right answer are great. He thought it was a response in "figuring out tactics to minimize effort and pain and intending to meet the set of rules set by the professor." The physics instructor has experienced students cheating when he taught an introductory college course for pre-med majors. He said "they cheated like crazy" because "they had an overwhelming motivation to get an A, like the students presented in your study." In addition, this physics teacher also experienced students cheating in his honors chemistry class. He admitted to teaching this course similar to the physics course described here, using a lecture mode with a rapid pace. He feels pressure to prepare them for subsequent chemistry courses and wishes to cover many topics. However, he attributes the students' cheating to "parent and peer pressure, the need to get a better grade, that they didn't study, and they get a "rush" when they cheat and don't get caught. There is no personal accountability or responsibility."

None of the instructors believe the students are learning much physics. Instead they were in agreement that the students were getting a "strange notion" of what science is about. The nature of the course "disinvites" them from being active learners. They may have been learning a few terms and some ideas, but were not picking up on the nature of science. The instructors agreed that there would be no way to get these students to willingly take a physics course again. The astronomer believed that students "compartmentalize" the science knowledge, and if they are fortunate enough to enroll in an "inquiry-based chemistry course" they may have a very good attitude toward chemistry, but still think of physics as "bad." The physics teacher states the students are learning "something, but they won't remember much--maybe a few names, maybe inertia or Newton." He sees little relevance to their lives, stating they will "learn physics has no importance in their lives. They will see it as something they have to do to get that piece of paper (diploma)."

In order to make physics more palatable to non-majors restructuring of the course would need to take place. The science educator stated that the reality of large lecture halls filled with many students needs to be faced. Also, teachers tend to teach in ways they've been taught, so educating the professor in different teaching methodology would be another good step. Another point made was that lectures need to be fewer and laboratory sessions need to be increased. The laboratories should be restructured so students are not given a set of instructions to follow, but should be told "what to accomplish, not the outcome they should get." Students should "gather data and generalize conclusions, not verify what the giver of information said is true." Students must be allowed to talk, be involved, and to make mistakes. A focus should be made on covering fewer physics concepts, but in covering the physics encountered in more depth.

The physics teacher had a somewhat different view, stating that he is unsure of the best method for teaching science. He asked, "Do you immerse them in so much--give them so many handouts and hope some of it sticks? Or do you go in depth in one area and ignore the rest?" He attributed some of the course's problems to the teaching assistant's inability to to help the students in lab get the right answers. He would advise the teaching assistant to "demonstrate the lab before or after so the students can see how it's supposed to be done." He also recommended that university science teachers take teaching

methods courses, because "at research universities they stick anyone in who's low on the totem pole. Their methods turn off students, and the students can't be turned back on." In fact, he talked about his own college experiences during which his physics professors would call it their "day in hell" every other year when they had to teach freshman physics.

Summary of Conclusions

The students in this classroom were typical transitional students, trying to be successful in their attempts to learn physics. The professor wished to help them be successful in their learning, and set up his course in a manner in which he believed would do just that. However, the structure of the course required the student activity to be much different than that expected by the professor, while offering the illusion that students were meeting the goals the professor had set out. The professor wanted the students to learn and enjoy physics. The behaviors designed by the students gave the impression they are learning and enjoying physics while allowing them to meet their own goals of passing the course with a respectable grade. The professor may not have realized it, but his goals were not being met.

Students entering the physics course appeared to do so with trepidation but hope that it would be better than they expected. They were often interested in the material under study but had difficulty understanding it. This was in part because of the structure enforced on them due to right answers being considered proof of learning. The activities engaged by the students did not contribute to most students' understandings of the content but rather to simply getting through the course. All the activities designed by the students focused on getting the correct answers to problems, obtaining and maintaining a good grade. They were not concerned with understanding the content, but were determined to get the "right" answers as manifested by "shimmying" lab data, figuring ways to gain the most points on homework problems, being known as a serious student by the professor, and if doing well, keeping it a secret from other students in order to protect their grade. The classroom environment encouraged students to work independently rather than cooperatively, and students were not stimulated to engage in active discussion of the ideas of physics but were inhibited even from asking questions of clarification. Many were not successful at making the adjustments required to pass this course or did not wish to attempt to make it through as is evidenced by the 50% drop out rate. Those who remained did so because they were required by their majors. Students did make it through, but did not seem to understand or enjoy physics. The methods the students used to pass physics allow them to get the right answers and to appear to learn and enjoy physics. No students in this course who had a choice intended to enroll in more physics. One student said,"I like science, but I won't take more physics. Maybe zoology or computers, but not for a long time."

The outcomes of this study are parallel to other studies of introductory physics courses. The traditional approach of physics instruction, with its emphasis on solving algorithmic problems, encourages students to concentrate on procedural rather than conceptual ideas of physics. The curriculum of the course is not well-matched to the student, but instead is matched to the professor. There are often significant differences between what the instructor thinks the students have learned and what they have actually learned (McDermott, 1990).

A starting point for improving physics instruction in a traditional classroom would be to uncover student thinking and build on their ideas (McDermott, 1990; Tobias, 1992). Students can often solve algorithmic textbook problems correctly, but lack conceptual understanding of the underlying idea. Allowing and encouraging students to share ideas without fear of ridicule, would enable the professor to know what students are actually learning. The professor would know in which direction instruction should proceed to address student perceptions. Woodhull-McNeal (1989) recommends allowing students the freedom to discuss, make mistakes, and to learn from those mistakes. Allowing the students to see that the professor does not know everything and can also make mistakes will encourage them beyond focusing on getting the right answer to understanding the concept. McDermott (1990) recommends use of surveys or student interviews to uncover student thinking in larger classes.

While recommendations for more active laboratory learning with fewer hours spent in traditional lectures are a good consideration (Caprio et al. 1989), without a restructuring of laboratory sessions students will still be focusing on getting the right answers instead of using their own data to draw conclusions. Students should be given a direction for their lab, and then asked to find a way to solve the problem (Tinnesand & Chan, 1987; Schamel & Ayres, 1992). In this way students are personally involved in the inquiry and are working toward solving a problem, not verifying what is already known to be right (Pickering, 1985), eliminating shimmying toward the already known correct answer.

What is taken as an assumption of understanding will effect how a course is structured. The professor of this course believed that students showed understanding through getting the right answers on their assignments. The course structure provided clues to students as to what, in their viewpoint, was valued in class. In order to increase conceptual understanding of the material there is a need to select different evidence of learning. Alternative assessments need to be explored to encourage students to persist in their science interests, yet maintain a high standard of learning. The use of portfolios proved successful in a Florida introductory chemistry class (Barrow, 1993). Assigning fewer problems over a longer period of time would not only allow students time to better conceptualize the problems, but would allow the professor time to provide better feedback to the students. Students could be asked to reflect on their problem solving in a journal which could accompany the homework to allow the professor to understand student thinking. Traditional curve grading inherent in this and other introductory courses, has the effect of discouraging student interaction. It encourages competition for the few high grades, and implicit in the grading system is that some people will fail.

With modification of the curriculum, these and other science shy students, will be able to meet the common student and professor goals of learning and gaining an appreciation for physics. Perhaps they will be encouraged to enroll in future physics and other science courses, and even to become physics majors.

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